The influence of texture on judgments of slant and relative distance in a picture with suggested depth

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Six surfaces from natural environments with different visual textures were photographed at angles of 60, 65, and 70 deg from perpendicular. Measurements were taken of 24 Ss' judgments of the inferred angles of slant and inferred midpoints of the six textured surfaces represented in the photographs which were viewed in the frontoparallel plane. Judgments of both slant and relative distance within the photographs were influenced by represented angle of slant and by variations in surface texture.

Interest in the role of visual texture as a variable in space perception has stemmed from the theory of Gibson (1950a). Embodied in the concept of psychophysical correspondence was the hypothesis that from a single, static, monocular texture density gradient, an O could obtain specific and veridical information about the slant and depth of a surface in the environment. Various experiments on the perception of optical slant (Beck, 1960; Gibson, Purdy, & Lawrence, 1955) and demonstrations involving the Ames distorting room, led Gibson (1966) to reject this original notion and to concede that from a single, static convergence point, it is possible for an O to obtain only ambiguous or equivocal information about the layout of environmental surfaces. The ambiguity of static perception is removed when locomotion of the O changes his viewing position through a series of convergence points. Surface texture remains important, however, since the slant of a surface "is specified by the continuous gradient of flow velocities of its optical texture [Gibson, 1966]."

Hochberg (1971) argues that although Gibson does not now place much stress on the importance of the static texture variable for a psychophysics of space perception, it remains important to determine the limits of the efficacy of this variable as a visual source of spatial information. Even though a single, static, texture density gradient cannot unambiguously specify the precise orientation of a surface in the environment, it may remain an important source of information for depth, particularly in combination with information contained in motion perspective. The present experiment investigated the influence of composition of texture on judgments of slant and relative distance, using photographic reproductions of several natural environmental surfaces.

Using artificially constructed surfaces, experiments by Gibson (1950b), Gibson and Gibson (1957), Flock and Moscatelli (1964), and Kraft and Winnick (1967) have shown that, with steepness of the gradient of texture density held constant, judgments of surface slant were influenced by regularity of shape and evenness of distribution of the elements comprising the texture of a

surface. Differences in number of textural units, their shape, absolute size and spacing, and area of the retina involved have also been found to influence slant judgments (Eriksson, 1964; Gruber & Clark, 1956; Phillips, 1970). Newman (1971) found that relative distance judgments of the midpoint of a surface differed with varying numbers of elements in the texture, and Wohlwill (1962) reported similar findings using textures to suggest depth in pictures. All these results indicate that, despite entirely constant gradients of texture density, variations in several specifiable properties of surface texture influenced judgments of slant and distance. It is not certain to what extent results from these experiments can be generalized, since most experiments have used surfaces that have textures constructed artificially in the laboratory. Gibson has not specified when a texture density gradient is above threshold. It thus remains uncertain whether the texture density gradients in these experiments were adequate and equivalent to those derived from naturally occurring surfaces in everyday environments. With natural surfaces, comparable results might not be obtained. To overcome this limitation and to obtain more ecologically valid textures, the present experiment employed colored photographs of natural environmental surfaces to provide the stimuli for judgments of slant and relative distance.

In most previous experiments, Ss have been required to judge the slants of surfaces viewed monocularly, through an aperture in a reduction screen. There is evidence (Gibson, 1950b) that, under such conditions, some Ss may suspect that they are looking at a picture in the frontal plane and not at a physically slanted surface. To avoid the possibility of Ss' experimental expectations distorting the results, in the present experiment the pictorial nature of the stimuli was not concealed from Ss. Ss were required to judge the inferred slant and inferred midpoint of a textured surface depicted in a picture. This introduces different problems of interpretation, but the results should indicate whether texture density gradients from several natural surfaces, irrespective of textural composition, can provide equally convincing representations of slant

and relative distance within a picture.

The experiment also examined the relationship between judgments of slant and judgments of relative distance. In Gibson's theory, gradients of texture density provide the information for judgments of both slant and relative distance. For the same surface, it would thus be predicted that there should be a positive correlation between slant judgments and relative distance judgments of the midpoint of the surface.

METHOD

Apparatus

Six natural environmental surfaces with different textures were photographed with the camera at slants of 60, 65, and 70 deg from the perpendicular. The camera was mounted on a tripod 38 cm above the surface and was stopped down to keep all parts of the photographs (35-mm color transparencies) equally in focus. All the physical surfaces selected were completely flat and large enough to fill the entire 35-mm slide, even with the camera at 70 deg from the perpendicular. The total physical lengths of surface portrayed in all photographs at each camera angle were as follows: 60 deg, 139 cm; 65 deg, 255 cm; 70 deg, 891 cm. The surfaces photographed were selected as having two different texture types as follows:

(1) Irregular Textured Surfaces

Pebbles on a shingled beach. They ranged in size from 15 to 2 cm in diam. This gave an irregular texture with relatively large, randomly distributed elements varying in size. *Concrete aggregate* on the flat roof of a car park. The surface was composed of many stone chippings, all about 2 cm in diam, imbedded in a cement mixture. This gave an irregular texture with small, randomly distributed elements of approximately constant size. *Grass* in a newly mown lawn. Individual blades of grass were not more than 3 cm tall. This gave an irregular texture with numerous, very small, randomly distributed elements, relatively constant in size.

(2) Regular Textured Surfaces

Paving stones on a sidewalk. These were all 92 x 62 cm and arranged systematically to give a regular, man-made texture with evenly distributed, large, rectangular elements. *Brick wall*, with each brick 22 x 11.3 cm. This gave a further regular, man-made texture, similar to the paving stones but with smaller elements. *Tiles* on the flat roof of a gymnasium. Each tile was 15.8 x 15.8 cm. This gave a regular, man-made texture similar to the brick wall, but with enhanced perspective, since the tiles were arranged in symmetrical rows and columns to give unbroken lines of tiles parallel to the line of sight.

Slides of the surfaces were projected from a Leitz Pradovit projector onto a vertical white cardboard screen to give an image 18 cm wide x 27 cm tall. Ss sat 170 cm from the screen and viewed the projected image of each textured surface in the frontoparallel plane. Since it was not intended to conceal the pictorial nature of the stimuli, Ss used unrestricted binocular vision. They were permitted some head movement, but distance from the screen was held constant by a headrest. A movable protractor was provided for measuring judgments of slant. A distance bisection marker, consisting of a .25-cm black magnetic disk, could be moved by E up and down the center line of the projected image. Its position in relation to the top and bottom edges of the projected image could be read from the position of a button magnet attached to a scale on the back of the screen.

Procedure

Twenty-four male and female Ss, with normal or corrected-to-normal vision, made slant and relative distance judgments. Several demonstration slides of other textured surfaces, including some photographed in the frontoparallel plane, were used to explain the testing procedure to Ss. For slant judgments, the 18 stimulus slides were presented in a different random order to each S. Ss were told that each slide represented a surface slanting away from the frontoparallel plane. They were to reproduce this inferred slant by adjusting the arm of a protractor away from the vertical on one trial and up from the horizontal on a second trial. Each S's mean judgment of slant for each surface was calculated from these two adjustments.

For relative distance judgments, the 18 slides were again presented in a different random order to each S. Ss were asked to imagine that they were positioned at the lower end of the surface and could see as far as the upper edge of the surface depicted on the screen. Within this portrayed distance, they were required to judge the position of the halfway point to the far end. When making judgments, Ss were not permitted deliberately to count the number of rows of texture elements between the near and far ends of the portrayed surface. On each surface, Ss made four relative distance judgments by instructing E when the portrayed midpoint had been reached. The starting position of the marker was arranged so that it moved in the conventional ascending, descending, descending, ascending direction on successive trials. On each surface, a S's distance bisection judgment was expressed as the average locus of the judged midpoint on four trials.¹

RESULTS

Table 1 shows the mean scores for judgments of slant in degrees and the mean scores for distance bisection judgments. A positive score indicates a judgment in which Ss placed the bisection marker beyond the true, portrayed midpoint of the surface, a negative score indicates a judgment in the reverse direction, i.e., an underestimation of the distance to the portrayed midpoint. The error sizes are expressed as the distances they represent on the portrayed surfaces.

Scores for slant judgments on the three irregular textured surfaces were initially combined for comparison with the combined scores for slant judgments on the three regular textured surfaces. Analysis of variance yielded a significant effect due to texture type (TT) (irregular vs regular), $F(1,23) = 11.41$, $p < .01$; a significant effect due to angle of represented slant (A), $F(2,46) = 85.7$, $p < .01$; and a nonsignificant TT by A interaction, $F(2,46) = 1.14$, $p > .05$. A further analysis of variance of the scores for slant judgments of the three irregular textured surfaces yielded a significant effect due to surface texture (T), $F(2,46) = 4.03$, $p < .05$; a significant effect due to angle of represented slant (A), $F(2,46) = 64.07$, $p < .01$; and a nonsignificant T by A interaction, $F(4,92) = 2.44$, $p > .05$. A similar analysis of variance of the scores for slant judgments of the three regular textured surfaces yielded a nonsignificant effect due to texture (T), $F(2,46) = .61$, $p > .05$; a significant effect due to angle of represented slant, $F(2,46) = 36.47$, $p < .01$; and a nonsignificant T by A interaction, $F(4,96) = .56$, $p > .05$.

Table 1
Mean Scores and Standard Deviations for Judgments of Slant and Judgments of Relative Distance

Judgment	Texture Type	Texture of Surface	60 Deg		65 Deg		70 Deg	
			Mean (Deg)	SD (Deg)	Mean (Deg)	SD (Deg)	Mean (Deg)	SD (Deg)
Judgments of surface slant at different angles of represented slant	Irregular Textured Surfaces	Pebbles	41.57	15.27	49.93	16.61	59.79	13.21
		Concrete Aggregate	50.57	13.73	54.63	13.13	60.04	12.13
		Grass	50.87	13.75	52.02	15.13	65.23	8.74
		Combined Mean	47.68		52.19		61.70	
	Regular Textured Surfaces	Paving Stones	51.80	15.40	57.85	14.87	64.10	13.38
		Brick Wall	51.91	13.57	60.16	10.68	66.42	10.05
		Tiles	52.80	13.67	57.30	13.50	64.90	11.38
		Combined Mean	52.17		58.44		65.14	
			Mean (cm)	SD (cm)	Mean (cm)	SD (cm)	Mean (cm)	SD (cm)
		Pebbles	-7.75	11.78	-27.92	21.85	-254.57	64.52
Judgments of the mid-point of surfaces at different angles of represented slant	Irregular Textured Surfaces	Concrete Aggregate	-0.52	16.35	-22.94	22.99	-229.00	64.93
		Grass	-6.48	12.18	-39.63	19.18	-206.19	124.30
		Combined Mean	-4.92		-30.16		-229.92	
	Regular Textured Surfaces	Paving Stones	-6.79	7.57	-24.84	11.64	-144.17	60.52
		Brick Wall	-4.70	8.69	-15.18	19.71	-172.69	59.40
		Tiles	-2.91	6.23	-10.00	18.37	-193.05	125.10
		Combined Means	-4.80		-16.68		-169.97	

Scores for distance judgments on the three irregular textured surfaces were similarly combined for comparison with the combined scores for distance judgments on the three regular textured surfaces. Analysis of variance yielded a significant effect due to texture type (TT) (irregular vs regular), $F(1,23) = 73.27$, $p < .01$; a significant effect due to angle of represented slant (A), $F(2,46) = 474.26$, $p < .01$; and a significant TT by A interaction, $F(2,46) = 57.41$, $p < .01$. A further analysis of variance of the scores for distance judgments for the three irregular textured surfaces yielded a significant effect due to texture (T), $F(2,46) = 3.98$, $p < .05$; a significant effect due to the angle of represented slant (A), $F(2,46) = 528.02$, $p < .01$; and a significant T by A interaction, $F(4,92) = 7.18$, $p < .01$. A similar analysis of variance of the scores for distance judgments for the three regular textured surfaces yielded a nonsignificant effect due to texture (T), $F(2,46) = 2.97$, $p > .05$; a significant effect due to angle of represented slant (A), $F(2,46) = 295.64$, $p < .01$; and a significant T by A interaction, $F(4,92) = 9.32$, $p < .01$. Table 2 shows the product moment correlation coefficients obtained, within groups of Ss, for judgments of slant and judgments of relative distance.

DISCUSSION

The results show that convincing impressions of slant and relative distance were produced in a picture by static texture density gradients from photographs of natural environmental surfaces. With all surface textures, increases in angles of represented slant gave significantly greater impressions of slant and depth. For slant judgments, angle of represented slant was consistently

underestimated but, at all angles of represented slant, different surface textures induced significantly different degrees of underestimation of represented slant. Specifically, the regular textured man-made surfaces gave significantly stronger impressions of slant than the irregular textured surfaces. This difference was probably due to rectangularity of element shape and clear gradients of linear perspective present only on the regular textured surfaces. Within this group of regular textured surfaces, however, variations between the surfaces in linear perspective (strongest on the tiled surface) and size of texture elements, which covaries with overall number and packing density of elements, had no significant effect on slant judgments. It was only within the group of irregular textured surfaces, lacking clear linear perspective, that size of texture elements seemingly influenced slant judgments. At most angles of represented slant, as size of elements decreased, impressions of slant increased (pebbles, through concrete aggregate, to grass).

Relative distance judgments followed the same

Table 2
Product-Moment Correlation Coefficients for Judgments of Slant and Judgments of Relative Distance

Texture of Surface	Angle of Represented Slant (Deg)		
	60	65	70
Pebbles	.001	.020	.287
Concrete Aggregate	.319	.199	.007
Grass	.303	.465*	.057
Paving Stones	.055	-.344	.085
Brick Wall	.149	-.093	.188
Tiles	.186	.301	.003

* $p < .05$ ($df = 22$)

pattern as slant judgments. Although all surface textures gave convincing impressions of depth, at all angles of represented slant, the true position of the portrayed midpoint was consistently underestimated on all surfaces. The regular textured surfaces gave significantly more veridical impressions of distance to the true midpoint than the irregular textured surfaces. Rectangularity of element shape and clear gradients of linear perspective on the regular textured surfaces again probably account for this result. The significant Angle by Texture Type interaction shows that the influence of texture type on relative distance judgments was particularly marked at the greater representations of slant which also portray surfaces of much greater physical length. At greater representations of slant and depth, towards the horizon there is a decrease in the ability to differentiate separate texture elements or judge the precise number of elements in the gradient. Under such conditions, other sources of distance information such as gradients of perspective may assume increasing importance. As with slant judgments, variations in linear perspective and element size between the regular textured surfaces had no significant consistent influence on distance judgments. Variations in element size between the irregular textured surfaces did, however, exert a significant influence on distance judgments, but at each angle of represented slant the effect of element size was less consistent than for slant judgments. The significant Texture by Angle interactions within both irregular and regular textured groups of surfaces may indicate a complex relationship between represented slant and depth and element size and number. A complex interaction would be predicted, since the loss of acuity for texture elements at greater degrees of represented slant and depth will vary with size and spacing of the texture units on the original physical surfaces.

The product moment correlation coefficients between slant judgments and distance bisection judgments were not large, but 16 out of 18 were positive. The very different laboratory operations used to obtain explicit judgments of slant and distance introduced different task and instructional sets that were not the same for both types of judgment. This would have reduced the common variance between them. The results, therefore, merely suggest a positive relationship between perceived slant and perceived relative distance, mediated by the separate influence of texture on both judgments. It should also be noted that, for distance bisection judgments on all surfaces, underestimation of the midpoint considerably increased, on a percentage basis, from 60, through 65, to 70 deg. Errors for slant judgments on all surfaces were, in general, more nearly veridical from 60, through 65, to 70 deg. This anomalous result does not support the prediction that both perceived slant and perceived distance were mediated by the same variable of texture. The increasing underestimation of the midpoint at greater angles of

represented slant may, however, be accounted for on a number of grounds, one being the blurring of the texture elements with receding distance. This effect would have provided a direct cue to slant, but a loss of information in regard to distance. Alternatively, Ss' actual judgments of the midpoints of the surfaces may have been biased towards underestimation by the presence of the rectangular frame formed by the boundaries of the photographic slides viewed on the projection screen. With increasing represented slant, Ss have to place the bisection marker increasingly nearer the top of the picture and further from the objective midpoint of the two-dimensional "picture frame" before them. This could have introduced a bias that influenced only distance judgments. It could also account for underestimation of distance per se.

In general, the results from this experiment demonstrate that several of the specifiable properties of surface texture that have been found to influence judgments of slant and distance with artificially constructed surface textures also influenced judgments with more ecologically valid surfaces. This confirms that the information in a single static texture density gradient is ambiguous, not only because it corresponds to a whole family of arrangements of surface slant and spacing of the texture elements, but also because certain textures provide intrinsically more distinct information than others. Results for both slant and distance judgments indicate that intrinsic differences in the information from identical gradients of texture density from surfaces with different textures become less marked when other, complementary gradients of stimulation (e.g., linear perspective) are also present. It remains to be determined if variable judgments of slant and relative distance would occur with different surface textures when motion perspective is also present. This would provide a more definitive test of Gibson's theory.

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NOTE

1. Conversion from errors in screen position to equivalent errors on the portrayed surface was achieved using the following relations: Portrayed-surface error = $H \tan (\beta + \phi) - H \tan (\alpha + \phi)$; $\alpha = \arctan (x/s) \tan \theta$; $\beta = \arctan [(E + x)/S] \tan \theta$; $x = S[\tan (\gamma - \phi)]/\tan \theta$; $\gamma = \arctan [\frac{1}{2} \tan (\phi + \theta) + \frac{1}{2} \tan (\phi - \theta)]$; where the parameters are: H = camera height, $2S$ = vertical length of the projected picture, ϕ = camera's angle of inclination, 2θ = optical angle of the projected picture (35 deg 20 min), E = error (at screen) of S's judgment.

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